MEAD CRATER, VENUS: AERODYNAMIC ROUGHNESS OF WIND STREAKS

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Introduction

Radar backscatter images of Venus returned by the Magellan spacecraft revealed many aeolian features on the planet's surface. While much work has focused on terrestrial wind streaks, the harsh environment of Venus limits direct measurement of surface properties, such as aerodynamic roughness, that affect aeolian features on that planet. However, a correlation between radar backscatter (σ_0) and aerodynamic roughness (z_0) for the S-band radar system on Magellan can be used to study the aerodynamic roughnesses of areas in which venusian wind streaks occur. The aerodynamic roughness of areas with both radar-bright and radar-dark wind streaks near Mead crater are calculated and compared to z_0 values measured on Earth in order to compare the surface of Venus with known terrestrial surface textures.

Background

The Magellan mission revealed the presence of aeolian features such as radar-bright and radar-dark wind streaks, dune fields, and possible yardang fields on Venus [1,2]. The orientations of these features are controlled by and follow the trends of the venusian winds [3]. Although aeolian features have been studied in relation to atmospheric circulation on a global scale, little work has dealt with the aerodynamic roughness of the areas in which wind streaks occur.

A quantitative relationship between radar backscatter and aerodynamic roughness has been developed by correlating field measurements of z_0 with radar backscatter measurements from the NASA/JPL Airborne Synthetic Aperture Radar (AIRSAR) [4] and from the SIR-C/X-SAR experiment [5]. The relationship can be used to determine aerodynamic roughness from radar backscatter data over large areas using remote sensing of planetary surfaces where *in situ* measurements would otherwise be impossible [6]. The Magellan radar data give near-global coverage of the venusian surface. However, the radar system operated in the S-band (λ = 12.6 cm) -- a band typically not used for terrestrial remote sensing and for which a direct correlation between σ_0 and z_0 has not been made. Because the S-band lies between the C- and L-bands (for which the correlations have been made), it is possible to interpolate values for the S-band data. *Blumberg* [5] assumed that there would be a simple trend in backscatter coefficients from C-band, through S-band, to L-band. Using terrestrial σ_0 and z_0 data in the C- and L-bands, he simulated S-band radar backscatter coefficients and correlated them to terrestrial z_0 measurements. Thus, this relation between z_0 and σ_0 can be used to calculate venusian aerodynamic roughnesses from Magellan radar data.

Data and Analysis

The synthetic aperture radar (SAR) system onboard the Magellan spacecraft operated in the S-band at a frequency of 2.385 GHz and returned data with a spectral resolution of 0.2 dB [7]. During the mission, the venusian surface was imaged at varying incidence angles and look directions, covering ~98 % of the planet. *Greeley et al.* [3] used the Magellan radar images to detect aeolian features and compiled a data base of more than 5900 wind streaks over the entire planet. For each feature, they recorded properties such as type, dimensions, and orientation. Although the data base was used to assess atmospheric circulation, it is also a convenient reference for further studies of the venusian surface and aeolian features. The data used in this study are the C1-MIDRs (Compressed Once-Mosaicked Image Data Records) at a resolution of 225 m/pixel, covering areas of 15°x15°. Each C1-MIDR is divided into 56 1024x1024 pixel framelets. Only those framelets covering areas of interest were used in this study. The region surrounding Mead crater (15°N, 65°E) was chosen for the abundance of aeolian features of different types in the area.

Individual framelets were processed by first converting the DN values for σ_0 to dBs by

$$\sigma_0=\left(\frac{\left(0.0118 Cos\varphi\right)}{\left(Sin\varphi + 0111 Cos\varphi\right)^3}\right)\bullet 10^{\left(\frac{\left(DN-1\right)}{5}-20\right)}\bullet 0.1$$

in which DN ranges from 1 to 251 and ϕ is the angle of incidence [6]. The aerodynamic roughness was then calculated following

$$\log(z_0) = -1.221 + 0.0906(\sigma_0)$$

in which z_0 is in meters and σ_0 is in decibels (dBs) [5]. The resulting values of z_0 for the areas of interest were binned in ranges and each range was assigned a color to produce an aerodynamic roughness map for that area. Because the slopes at the streak locations are small [3], it was assumed that the radar backscatter was not significantly affected by topography in the vicinity of the streaks.

Discussion and Conclusions

A typical area for this study is shown in figure 1 and has both bright and dark streaks. Radar-bright streaks appear to be eroded areas over terrain with a z_0 range of 0.0001 to 0.0009 m. The radar-bright streaks themselves are generally rougher than the surrounding terrain, having z_0 values from 0.0009 m at the edges of the streaks to greater than 0.0017 m at their centers. Radar-dark streaks, however, are caused by deposition of windblown material [2]. These streaks are oriented in the same direction as the radar-bright streaks but are smoother than the surrounding terrain (which has z_0 values generally > 0.0013 m). The radar-dark streaks have z_0 values ranging from 0.0005 to 0.0013 m and are commonly aerodynamically smoother at their centers. The wind streaks studied here reveal several interesting aspects of radar-bright and radar-dark streaks. Although there is some overlap in the aerodynamic roughnesses of the two types of streaks, the bright streaks have higher z_0 values than the dark streaks. In fact, the radar-dark streaks appear to cover terrain that is similar in z_0 to the radar-bright streaks.

Aerodynamic roughnesses of the venusian wind streaks were compared to areas on Earth [8]. The z_0 values of radar-dark streaks correspond to values measured on a playa at Lunar Lake, NV, and to values measured over non-mantled pahoehoe lava. The radar-bright streaks are slightly rougher with z_0 values similar to those measured over alluvium at Golden Canyon in Death Valley, CA. Results of this study show that aerodynamic roughness calculations can be used to gain insight into the venusian surface.

Figure 1. A portion of C1-MIDR 15N060, framelet 56, showing radar-bright and radar-dark wind streaks caused by winds from the north. Image is ~50 km across.

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